Global Terrestrial Ecosystems Climate-Regulation Services Calculator

User's Manual

www.ecosystemservicescalc.org

Background

Terrestrial ecosystems play an important role in climate regulation, influencing climate both through the exchange of greenhouse gasses with the atmosphere (*biogeochemical* mechanisms) and by influencing the energy budget of the land surface (*biophysical* mechanisms)[1,2].

In terms of greenhouse gases, terrestrial ecosystems play a significant role in regulating atmospheric concentration of the greenhouse gasses carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Forests alone sequester 2.4 Pg carbon per year[3]. Forests also store vast amounts of carbon in vegetation and soil that could be released to the atmosphere as CO_2 if the forest were cleared. From 1990 to 2007, gross CO_2 emissions from tropical deforestation were equal to ~40% of global fossil fuel emissions[3]. Agricultural ecosystems also play an important role in global greenhouse gas budgets; agriculture has contributed ~14% of total global GHG emissions in recent years[5,6], but more sustainable agricultural practices have the potential to help reduce greenhouse gas emissions[7 9].

Terrestrial ecosystems also strongly affect climate through their control over the energy balance of the land surface[10 15]. Vegetated surfaces—especially forests—typically absorb more incoming solar radiation than empty fields, and in this sense have a warming effect on the land surface. The reduction in net radiation (R_{net}) associated with deforestation has a cooling effect on the climate[10,15,16]— sometimes even outweighing GHG-induced warming[10]. Counteracting this, clearing vegetation reduces transfer of water vapor to the atmosphere (evapotranspiration) and associated cooling of the land surface (latent heat flux) (*LE*). Without the vegetation, energy normally used to evaporate water instead heats the land surface[11,12,15 17]. Understanding the counteracting effects of R_{net} and *LE* is key to quantifying the climate regulation values (*CRV*s) of different ecosystems[1,7].

The *CRV* calculator is based on the *CRV* metric developed by Anderson-Teixeira et al. (2012)[7,18], which quantifies the climate regulation value of maintaining an ecosystem over a multiple-year time frame (e.g., 50 years). *CRV* characterizes changes in the surface energy balance of an ecosystem compared to a barren baseline, expressing the climate regulation value of the ecosystem in CO_2 equivalents—a common currency for carbon accounting. *CRV* combines biogeochemical (*GHGV*) and biophysical climate regulation services into an integrated index of ecosystem *CRV* (Fig. 1). The calculation combines modest radiative forcing from globally distributed greenhouse gasses with strong local radiative forcing from biophysical mechanisms by dividing local effects by global surface area. Because the non-local biophysical effects of changes in cloud formation and precipitation elsewhere in the world are not included in this calculation, *CRV* does not characterize net effects on global climate, but rather provides an integrated index of the direct effects of land clearing on the land surface energy budget.

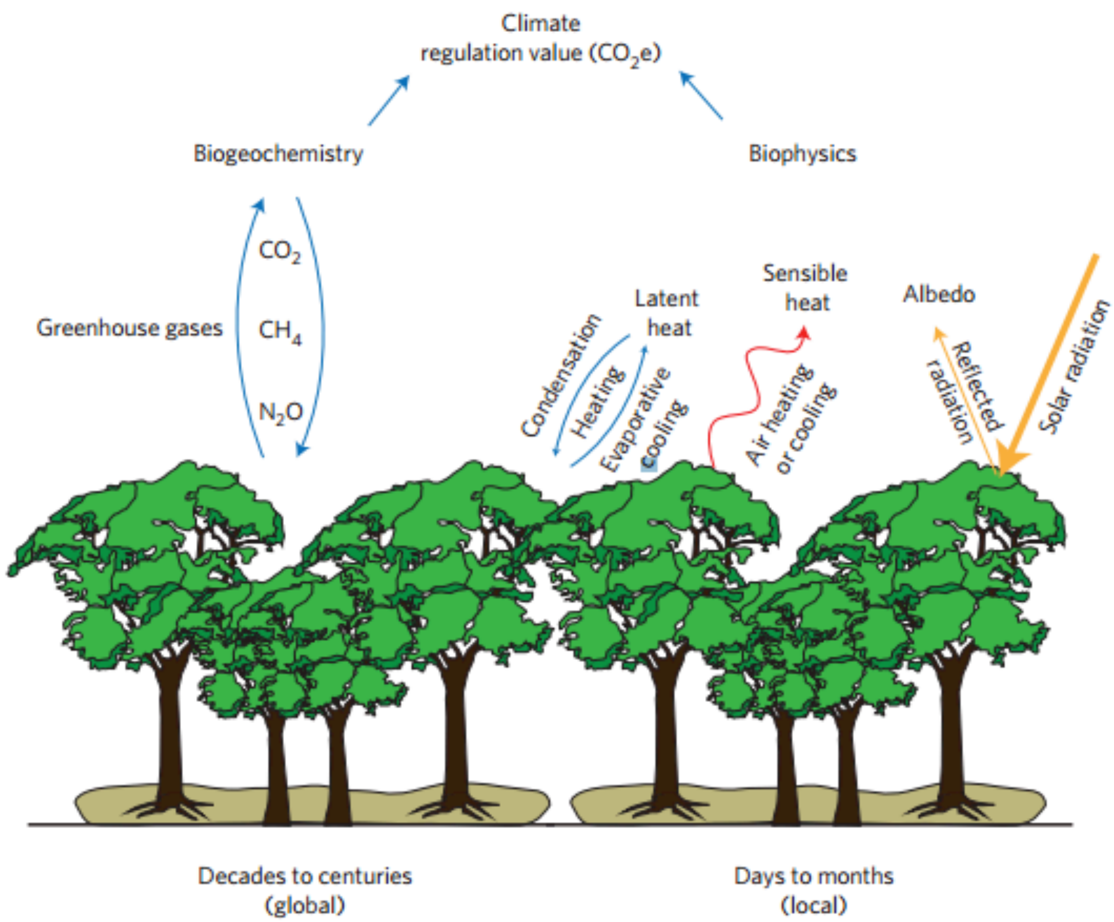


Figure 1. Schematic diagram illustrating how ecosystems influence climate through both biogeochemical and biophysical mechanisms. The climate regulation value index combines these services into a single index, which is expressed in carbon dioxide equivalents (CO_2-eq). Figure from Hungate & Hampton (2012)[18]*, based on Anderson-Teixeira et al. (2012)*[7]

Getting Started

The calculator operates on a single screen featuring a world map interface from which ecosystems can be selected and edited (Fig. 2). After the calculations are run, the map serves to identify locations corresponding to each selected ecosystem.

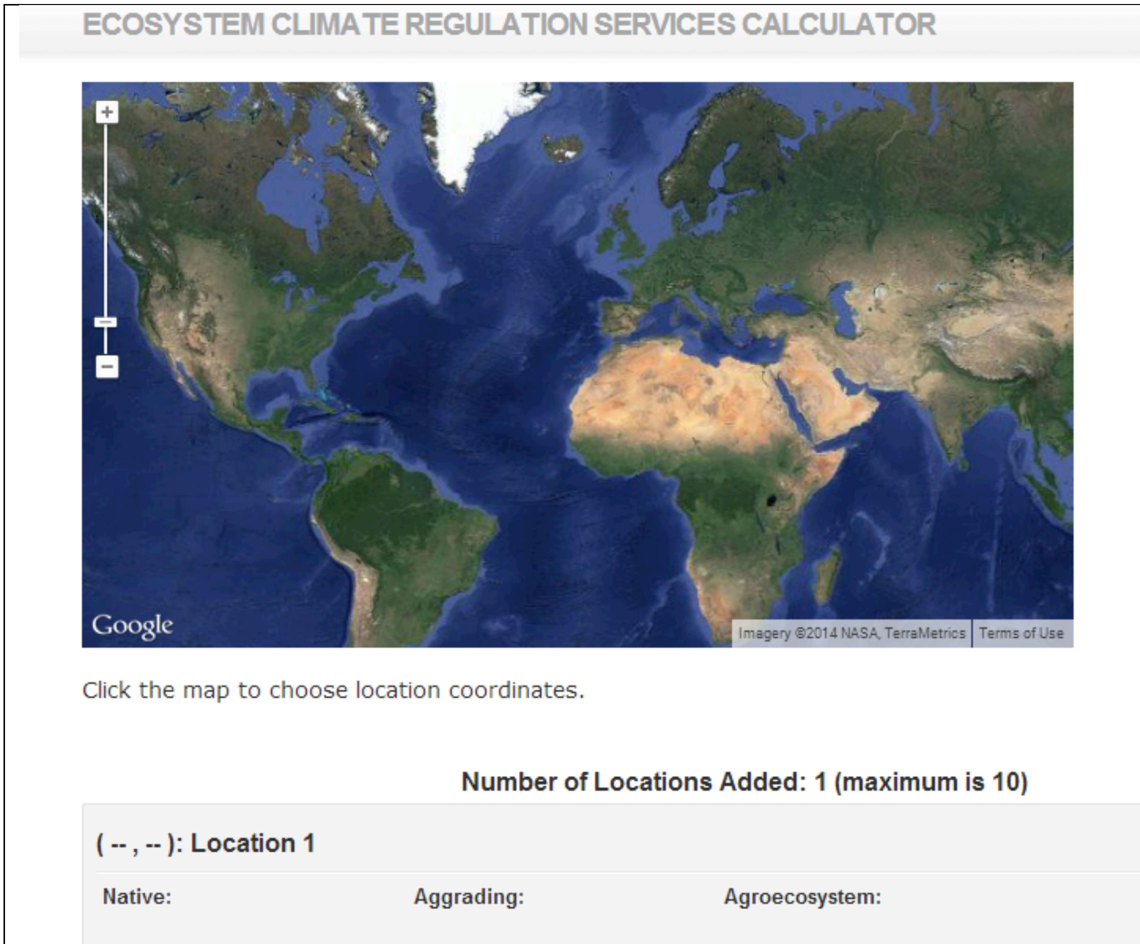


Figure 2. Global map interface of the CRV calculator. The default image is a standard world map.

Selecting Ecosystems

Selecting a location

1. Click on the location of interest on the map (note that the map's capacity to zoom and pan).
2. Scroll down to view the grey box identifying ecosystems that may be present at that location (Fig. 3), and select ecosystems of interest.

Adding additional locations

1. Click “Add Additional Location” button and repeat the steps above. *It is important to remember to select “Add Additional Location” before selecting another location on the map. If this button is not selected, the most recently selected location will be overwritten.*
2. Up to ten locations may be selected at for each run.

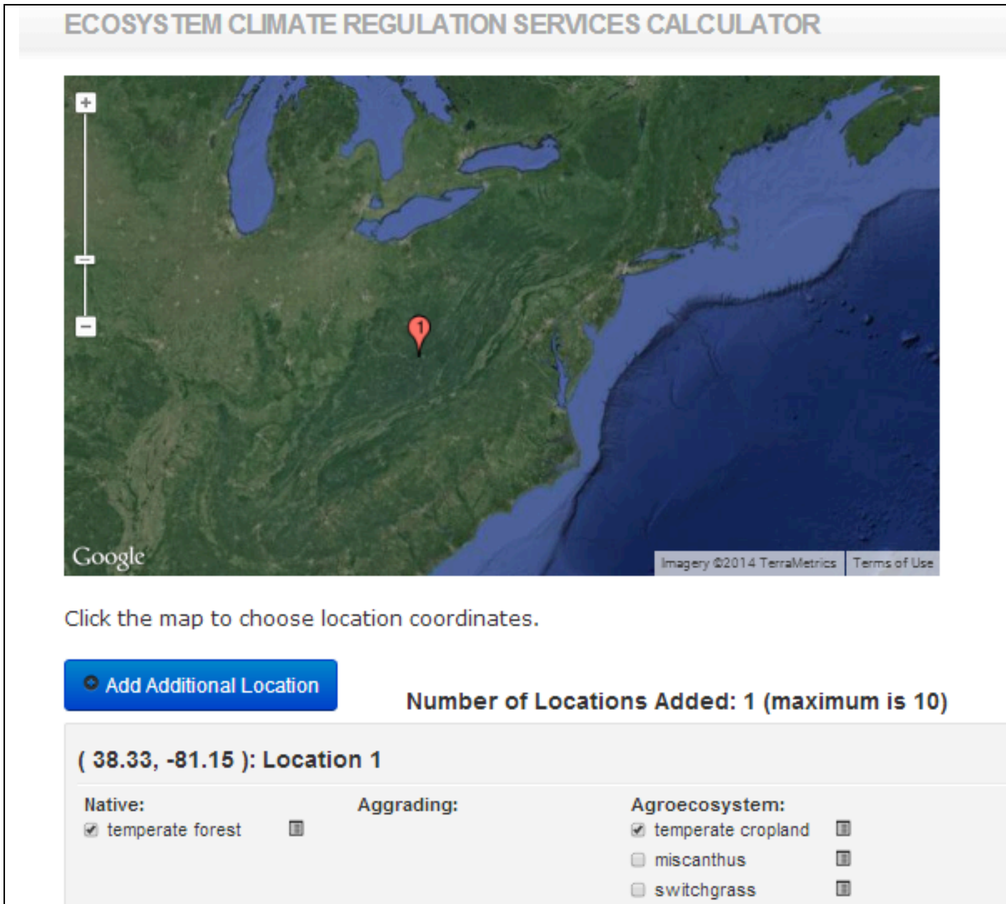


Figure 3. Illustration of how to select locations and ecosystems at that location. In this example, a location is selected where the native vegetation type is tropical forest, but agriculture is also present.

Editing Ecosystems

Why edit ecosystems?

Editing ecosystems can serve to ensure that calculations are based upon the best available locally specific data. In the current version of the calculator, default values are either locally specific (biophysical attributes) or based upon typical attributes of the selected biome type (biogeochemical attributes). The latter can often be improved by drawing upon data from global maps of climatically significant ecosystem properties (for example, aboveground biomass, soil carbon) that are loaded in the calculator and can replace default values at the user's discretion (Fig. 4; see below for note on discretion).

A)

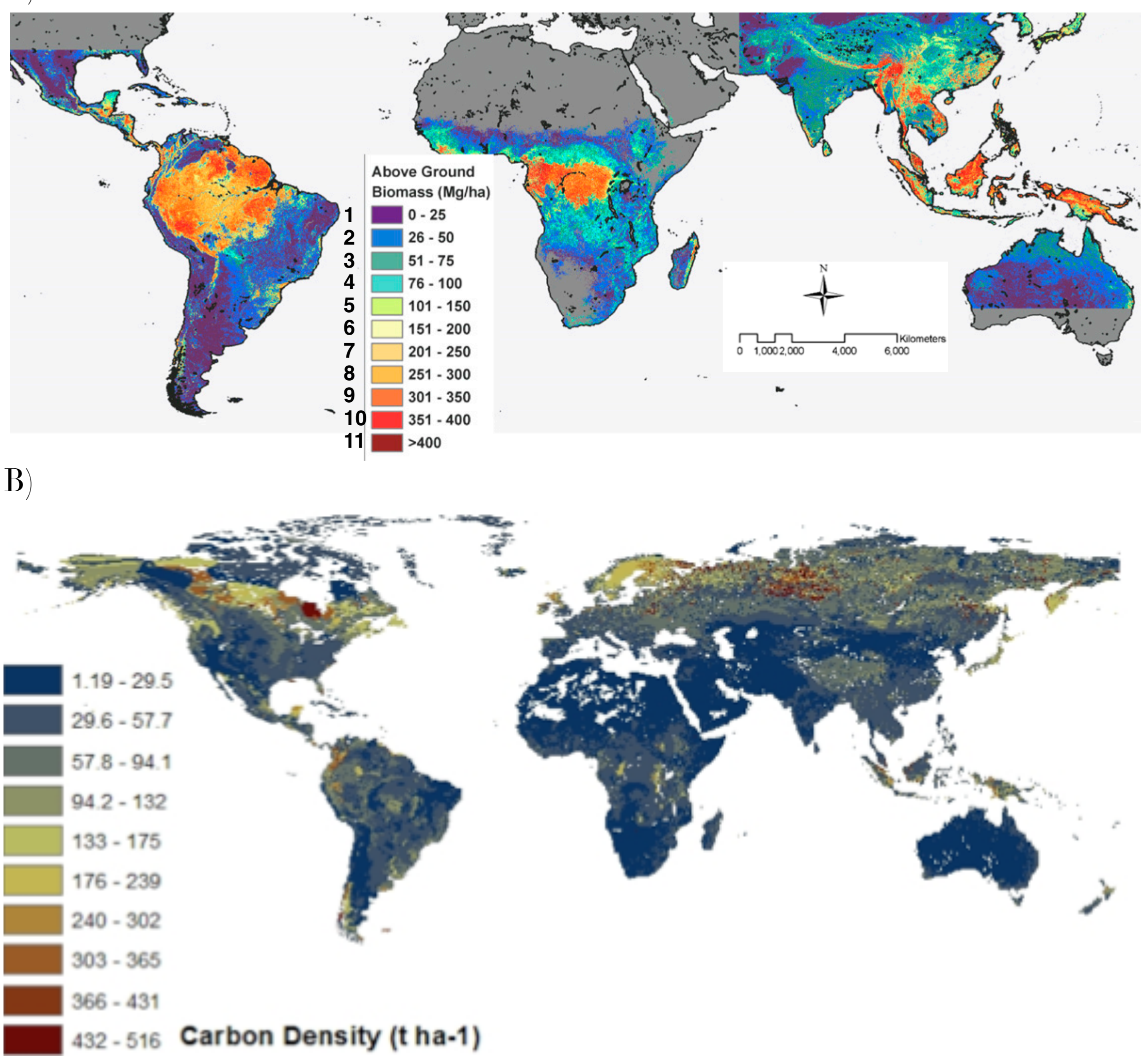


Figure 4. Two maps of climatically significant ecosystem properties from which values can be selected for calculations. A) Pantropical map of aboveground biomass c. 2000[19]*; B) Soil organic carbon in the top 30cm of soil* (Source: European Soil Data Center[20]).

How to edit ecosystems

1. To edit the properties of an ecosystem, click on the icon following its name. This will open a box with expandable bars for each category of climatically significant ecosystem properties.
2. Click on the category of interest. For example, the category "Initial Storage of Organic Matter" contains the variables aboveground biomass, root biomass, and potential soil organic matter loss (estimated at 30% of SOC in top meter of soil[21]). Note that it is sometimes necessary to scroll down to view all variables.
3. Use the dropdown menus to select default values (usually Anderson-Teixeira and DeLucia, 2011[21]), an alternative data source (for example Saatchi and others, 2011[19]; Fig. 4A, Fig. 5), or a user defined value.
4. Note: *It is critical to remember to check boxes to select the ecosystems that are edited; they are not automatically selected*.

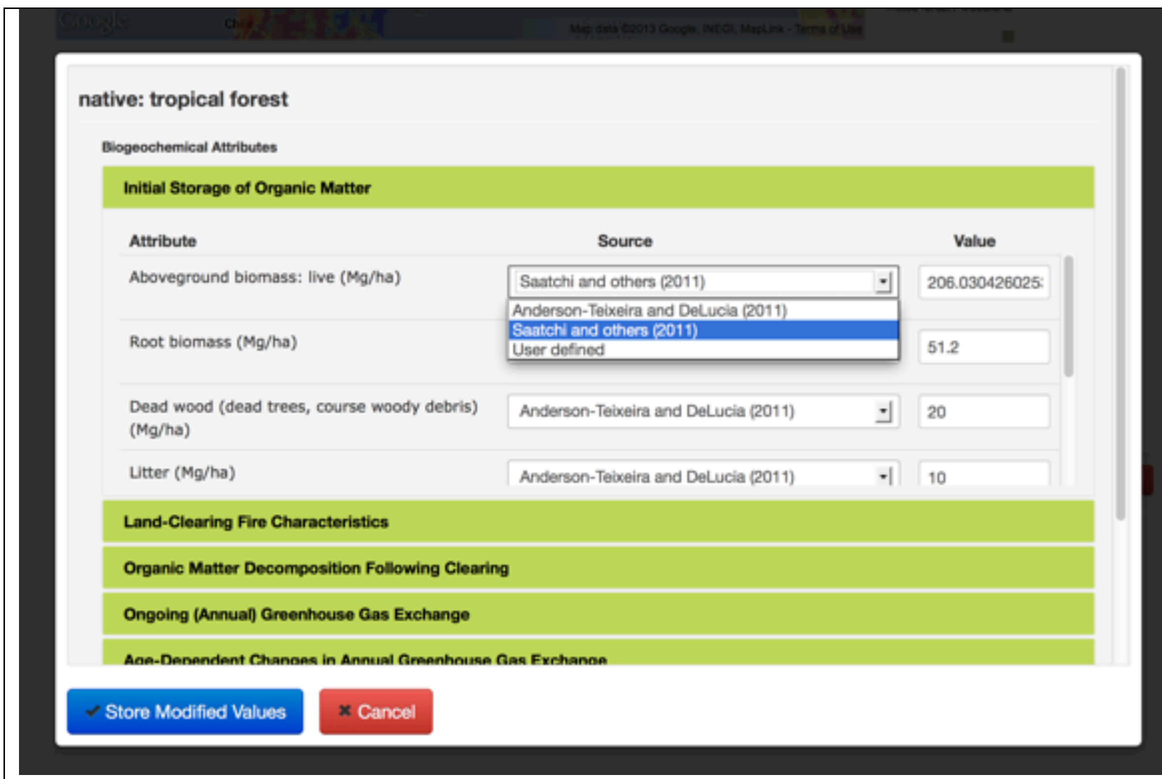


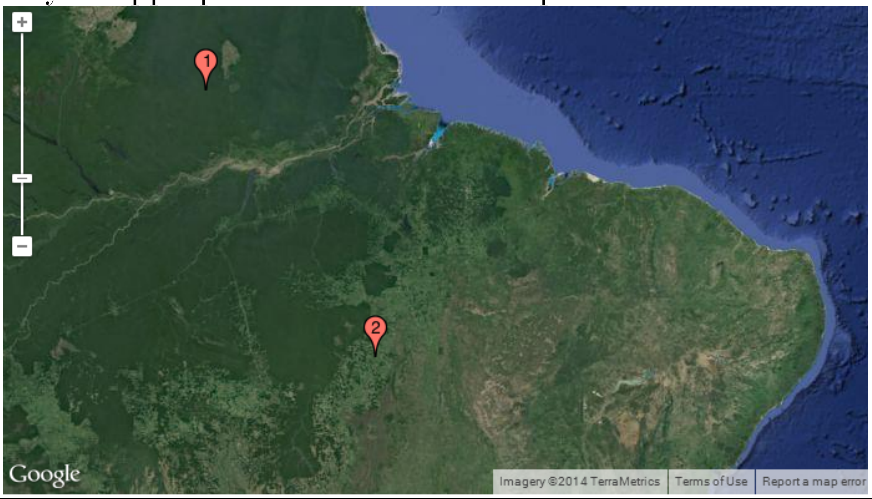
Figure 5. Illustration of how to edit ecosystem attributes in the CRV calculator. In this example, the default value (Anderson-Teixeira and DeLucia, 2011[21]) is being replaced by a value from a pantropical map of aboveground biomass (Saatchi and others, 2011[19]; Fig. 4A).

Discretion in editing ecosystems

Discretion is required in replacing default values with data from global maps because *global maps represent the on-the-ground reality at the time the measurement was made, whereas default values represent typical values for representative ecosystems.* So, for example, in an area where forest (native vegetation) has been converted to pasture, the default value would give a reasonable estimate of the biomass that may be expected for forest in that region, whereas the value from the aboveground biomass map included in the calculator (Fig. 4A) would give a value representative of pasture (Box 1).

The trustworthiness of values drawn from maps can be assessed by comparing with default values. If the mapped value is similar to that of the default (within ~ 30%), this indicates that it is likely a better estimate than the default. In contrast, if the value is very different, this indicates a mismatch between the selected ecosystem and the ecosystem present at the time the map was made. Box 1 gives an example of both instances.

Box 1. An example illustrating cases when it would and would not be appropriate to replace default values with those from underlying maps. Take two locations in the Brazilian Amazon: Location 1 (not affected by deforestation) and Location 2 (near the deforestation frontier). At both locations, the native biome is tropical forest. When editing the aboveground biomass value for Location 2, we find that the Saatchi et al.[19] (Fig. 4A) estimate is 269 tons/ha—more than the default estimate of 248 tons/ha. In this case, it is clearly appropriate to apply the location-specific value. In contrast, the Saatchi et al.[19] estimate for Location 2 is only 12 tons/ha. In this case, it is clear that this location was deforested at the time the Saatchi estimates were made. While it would not be appropriate to apply this estimate to calculate the value of the forest, it may be appropriate as an estimate of pasture biomass.



Running the Calculator

1. Once ecosystems are selected and edited, scroll to the bottom of the page.
2. Run the calculator.

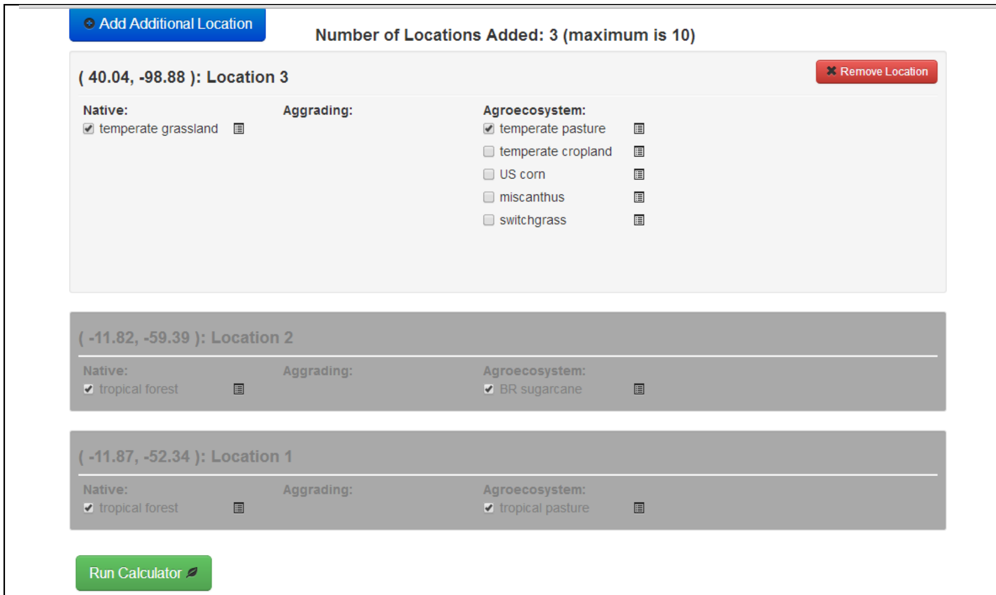


Figure 6. Example of a ready-to-run setup. Here, tropical forests from two locations and temperate grassland (from a third location) are being compared.

Interpreting Output

Understanding CRV and GHGV numbers

- **Results are presented in units of CO_2-equivalents per hectare** over the selected number of years (50 in this case). In other words, *CRV* or *GHGV* quantifies how many (metric) tons of CO_2 would have the same effect on climate as clearing one hectare of the ecosystem (and measuring the impacts over the selected time frame).
- **Positive values indicate that a given ecosystems has a net cooling effect on the atmosphere and clearing this ecosystem would result in warming of the atmosphere.** Negative values represent that the extant ecosystem has a net warming effect on the atmosphere.
-

Interpreting the CRV of single ecosystem

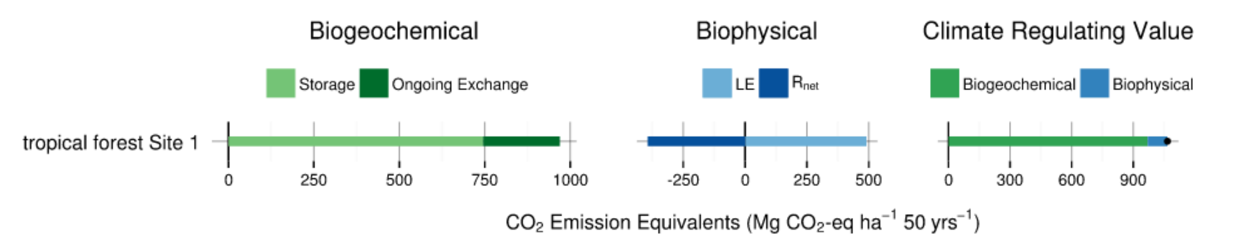


Figure 7. Sample output of the CRV calculator for an Amazonian tropical evergreen forest.

A typical output graph is shown above (Fig. 7). The three panels represent:

1. ***Biogeochemical***:
   a. *"Storage" Contribution to GHGV from* ***initial storage*** *of organic material*. If the ecosystem is cleared, carbon stored in vegetation, non-living organic material, and soil will be released to the atmosphere as CO_2. If fire is used to clear the ecosystem, other GHGs will also be released (e.g., CH_4, N_2O).
      "Ongoing Exchange"- Contribution from displaced from ***ongoing exchange*** *of GHGs between the ecosystem and the atmosphere.*

   b. *Every year, ecosystems exchange GHGs with the atmosphere. For example, many natural ecosystems take up CO_2 from the atmosphere, and croplands release N2O as a byproduct of nitrogen fertilization. If the ecosystem is cleared, such GHG exchanges will be displaced. Displaced GHG exchange is counted over the time period of interest (50 years in this case.)*

2. ***Biophysical:*** *Biophysical* is the sum of the contributions from (R_{net}) storage and

(*LE*) flux.

   a. ***R_{net}***- Net radiation, or the total incoming solar energy absorbed minus that which is reflected/ emitted back to space. This is highest in ecosystems where the vegetation is darker than bare ground for part or all of the year (e.g., boreal forest, vegetation on sandy soils).
   b. ***LE***- Latent heat flux, or the heat energy used to transform water from the liquid to the vapor phase (resulting in water vapor release to the atmosphere, or evapotranspiration). This will be highest in warm and wet climates.

   Note: biophysical values are not available for all ecosystems. They are available for all native ecosystems and a number of agroecosystems. When data are not available, no values will appear on output graphs.

3. ***Total Climate Regulating Value (CRV).*** *CRV* is the sum of biogeochemical and biophysical components.

Calculating the Impact of Land use Change

CRV (or GHGV) is measured relative to a bare-ground baseline. If you want to compute the full GHG effects of **land use change,** you will take the **difference between *CRVs* of the new and old ecosystems.**

So, for example, the total climate cost of clearing tropical forest (typical CRV = ~1400 *Mg* $CO_{2\text{-}eq}$) to make way for soy cropland (typical CRV= ~75 *Mg* $CO_{2\text{-}eq}$) is:

$$CRV_{tropical\_soy} - CRV_{tropical\_forest} = 75 - 1400\ Mg\ CO_{2\text{-}eq}/ha \text{ over 50 years}$$

$$= -1325\ Mg\ CO_{2\text{-}eq}/ha \text{ over 50 years}$$

The cost of this land use change is equivalent to releasing 1325 tons of CO_2 to the atmosphere.

Downloading Data

After running the calculator, data may be downloaded using the "Download CSV" button below the graphs (Fig. 8).

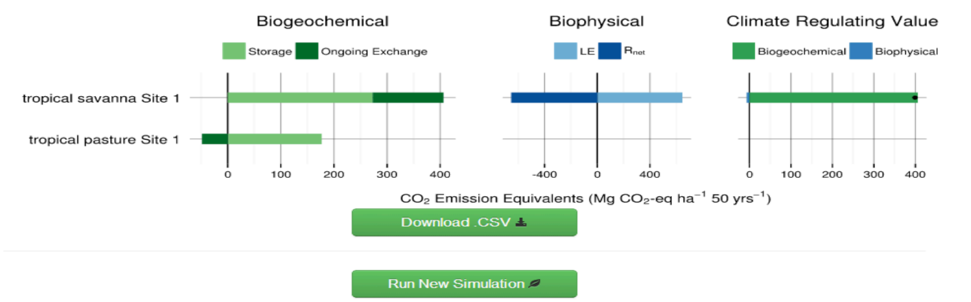
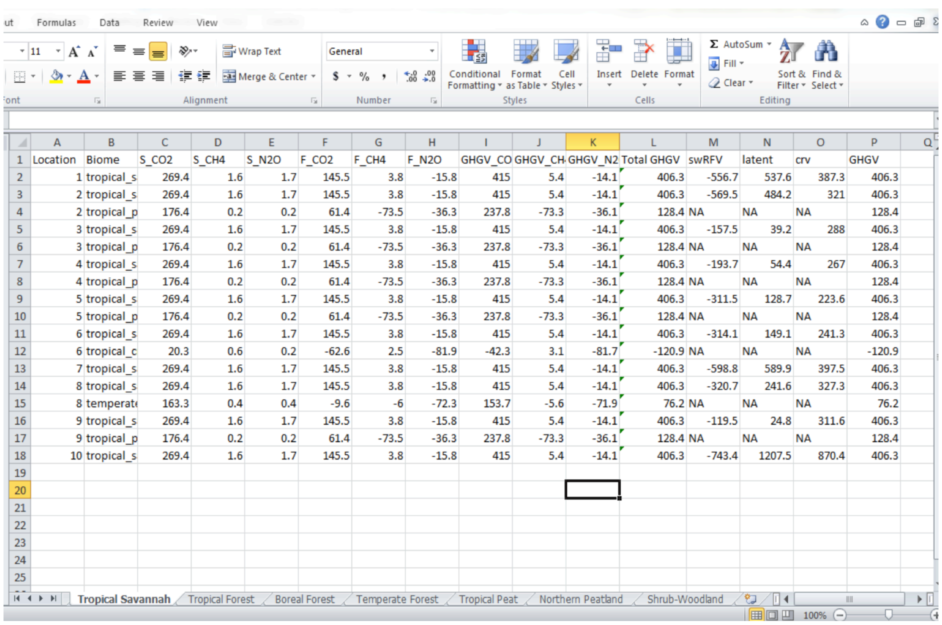


Figure 7. Downloading the data

Downloaded data is in .csv format and can be saved and viewed in any appropriate application (for example, Microsoft Excel; Fig. 8).



Location	Biome	S_CO2	S_CH4	S_N2O	F_CO2	F_CH4	F_N2O	GHGV_CO	GHGV_CH	GHGV_N2	Total GHGV	swRFV	latent	crv	GHGV
1	tropical_s	269.4	1.6	1.7	145.5	3.8	-15.8	415	5.4	-14.1	406.3	-556.7	537.6	387.3	406.3
2	tropical_s	269.4	1.6	1.7	145.5	3.8	-15.8	415	5.4	-14.1	406.3	-569.5	484.2	321	406.3
2	tropical_p	176.4	0.2	0.2	61.4	-73.5	-36.3	237.8	-73.3	-36.1	128.4	NA	NA	NA	128.4
3	tropical_s	269.4	1.6	1.7	145.5	3.8	-15.8	415	5.4	-14.1	406.3	-157.5	39.2	288	406.3
3	tropical_p	176.4	0.2	0.2	61.4	-73.5	-36.3	237.8	-73.3	-36.1	128.4	NA	NA	NA	128.4
4	tropical_s	269.4	1.6	1.7	145.5	3.8	-15.8	415	5.4	-14.1	406.3	-193.7	54.4	267	406.3
4	tropical_p	176.4	0.2	0.2	61.4	-73.5	-36.3	237.8	-73.3	-36.1	128.4	NA	NA	NA	128.4
5	tropical_s	269.4	1.6	1.7	145.5	3.8	-15.8	415	5.4	-14.1	406.3	-311.5	128.7	223.6	406.3
5	tropical_p	176.4	0.2	0.2	61.4	-73.5	-36.3	237.8	-73.3	-36.1	128.4	NA	NA	NA	128.4
6	tropical_s	269.4	1.6	1.7	145.5	3.8	-15.8	415	5.4	-14.1	406.3	-314.1	149.1	241.3	406.3
6	tropical_c	20.3	0.6	0.2	-62.6	2.5	-81.9	-42.3	3.1	-81.7	-120.9	NA	NA	NA	-120.9
7	tropical_s	269.4	1.6	1.7	145.5	3.8	-15.8	415	5.4	-14.1	406.3	-598.8	589.9	397.5	406.3
8	tropical_s	269.4	1.6	1.7	145.5	3.8	-15.8	415	5.4	-14.1	406.3	-320.7	241.6	327.3	406.3
8	temperat	163.3	0.4	0.4	-9.6	-6	-72.3	153.7	-5.6	-71.9	76.2	NA	NA	NA	76.2
9	tropical_s	269.4	1.6	1.7	145.5	3.8	-15.8	415	5.4	-14.1	406.3	-119.5	24.8	311.6	406.3
9	tropical_p	176.4	0.2	0.2	61.4	-73.5	-36.3	237.8	-73.3	-36.1	128.4	NA	NA	NA	128.4
10	tropical_s	269.4	1.6	1.7	145.5	3.8	-15.8	415	5.4	-14.1	406.3	-743.4	1207.5	870.4	406.3

Figure 8. Values as shown after downloading CSV file.

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